Title: FLC Award: Smart Chutes and Sensors

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FLC Award: Smart Chutes and Sensors

1. Please explain your technology, the problem it solves and its benefits.

Increasing the production and use of biofuels is a national objective for renewable, cleaner energy. A primary objective of the Department of Energy's Bioenergy Technologies Office (BETO) Feedstock-Conversion Interface Consortium (FCIC) is to address the operational, safety, throughput, and yield of bio-refineries to revolutionize biomass processing with the goal to make bio-derived fuels cost-competitive with fossil fuels.

One of the main hurdles is increasing the operational reliability of the bio-refineries. Bio-refineries convert the biomass, such as corn stover, into ethanol. Corn stover is composed of the non-edible stalks, leaves, cobs, and husks left over from harvesting. This material is known for having poor processing properties for bulk solids handling and transport. These properties, such as moisture content, cause costly system plugging and downtime at bio-refineries which limit biofuel from being cost-competitive with diesel and gasoline fuels.

To address these system issues, Los Alamos and Jenike & and Johanson have combined "smart" transfer chutes with acoustic moisture sensors to update biomass processing by preventing overly moist biomass from plugging process lines and causing downtime.

With over 55 years of transfer chute design experience, Jenike & Johanson has evolved the standard stationary chute into a dynamic transfer chute design. This evolution includes the application of Jenike & Johanson's proprietary Discrete Element Modeling (DEM) software for handling biomass bulk. DEM analyzes how bio solids flow to simulate the motion or flow of a collection of particles such as corn stover. DEM takes into account the particle-particle interactions to calculate the total force experienced by individual particles in a bulk material to determine their accelerations, velocities and positions over a period of time, as it occurs in bio-refinery processing. Jenike & Johanson developed the hopper and chute designs specifically for industrially relevant material properties of corn stover.

A missing component in the Jenike & Johanson "smart" transfer chutes was the ability to monitor the moisture at the plug-screw feeder to reduce the wear on the component enabling a proper seal within the hopper.

Los Alamos' novel acoustic sensors quantify bulk moisture content using sound speed and acoustic signal amplitude analysis. This provides real-time monitoring (millisecond sampling rate) enabling the "smart chute" to detect and divert the high moisture content corn stover to be dried out and used later. This reduces plugging in the plug-screw feeder making the process more effective and preventing the integrated bio-refinery from shutting down. This sensor reduces the wear-state of the machinery thus increasing its operating life-time. Many acoustic sensors can be applied throughout the handling train to monitor moisture content at each stage within the bio-refinery process. Currently, the target location of these acoustic moisture sensors is at the bottom of the feed hopper supplying corn stover to the "smart" transfer chute. When the acoustic moisture sensor detects moisture contents greater than 35%, the smart chute diverts the high moisture content.

When the moisture content returns to acceptable levels (<30%), the smart chute reactivates and directs incoming feedstock back into the integrated bio-refinery process. The incoming feedstock that was diverted from the process (i.e., "rejected") is collected and further processed to an acceptable moisture level before being reintroduced to the process. The acoustic sensors are integrated into the feedstock hopper which begins the bulk solids handling and transport process. While the actual location can be flexible and depends on an integrated bio-refinerys' plant design, the sensors are placed in-line for continuous monitoring of moisture content; enabling state-of-the-art process control strategies. Operationally, the acoustic transmitter sends a low-frequency sound wave that penetrates through the corn stover. The transmitted acoustic waves are received through the use of a second acoustic receiver. Changes in the transmitted and received sound waves are directly proportional to the moisture content of the corn stover. Jenike & Johanson and Los Alamos have separately developed and tested their specific components of the smart chute system, which will be integrated together later this year.

The combination of smart chutes with continuous in-line acoustic sensor technology has the following benefits:

- Increases integrated bio-refinery time-on-stream
- Offers advanced process control strategies
- Enhances product selectivity, conversion, and yields
- Actively controls incoming feedstock quality
- Improves integrated bio-refinery plant operations
- Decreases maintenance downtime and costs

- Increase the operating life-time of the integrated bio-refinery

2. Who/what are or will be the markets or consumer of this technology?

Los Alamos' acoustic moisture sensors enable the "smart" transfer chutes to reconfigure during biomass handling and transport. The cost of plugged transfer chutes and processing stoppages is significant in industries beyond biomass. This integrated novel technology could also be applied to bulk solids handling and transportation in the pharmaceutical manufacturing, wood-composite, mining, food-processing, and biochemical industries. Similar to bio-refineries, their operations are based on processing significant amounts of bulk material, and processing efficiency and work stoppage are sensitive to moisture content. In addition to increasing the production rates of integrated bio-refinery smart chutes and acoustic sensors can improve "flowability" of materials and operations reliability for any moisture-sensitive bulk handling applications.

This uniquely transformable chute that automatically reconfigures based on material variability can revolutionize how a processing plant operates and adjusts to bulk material that is out of specification. It would allow processing plants to be proactive in making a feedstock change before out-of-spec material enters the plant and disrupts operation.

Sensing the moisture content of bulk solids on the incoming conveyor in real time will detect unacceptable ranges of moisture content. This information would allow operations to make process adjustments that reduce downtime. Thus, the plant efficiency could be improved.

Insufficient moisture presents safety and handling problems, too. Overly-dry materials can project unsafe volumes of dust into the air, causing breathing problems, clean-up delays, excessive wear and tear on machinery, and possible dust explosions. The smart chutes acoustic calibration is sensitive to too-high and too-low levels of moisture content.

- Where dry goods and powders are concerned (food and non-food), it is important to note the relevance of "smart" chutes for safety and quality assurance purposes. Moisture alarm content is a specification not to be exceeded in order to prevent mold growth in dry goods. Conversely when moisture content is too low in dried foods, the product can become stale and lose its taste appeal.

- In the pharmaceutical industry there are precise regulations regarding moisture content, and heavy fines and product recalls can be incurred if products are noncompliant. Moisture affects the properties of active ingredients such as chemical stability, crystal structure, powder flow, and dissolution rate. High volume, high unit count production demands rapid detection of out-of-spec components. “Smart” chutes enable manufacturers to consider transitioning from “as designed” quality control to an “as formulated” method.

- In the chemical formulation industry, excessive moisture can lead to clumping that degrades mixing quality. Alternatively, inadequate moisture content can be induced during drying, which can affect granulation and product degradation. Examples of dry formulations include wood pulp, detergent, and urea formaldehyde powder which is used for its thermosetting properties in adhesives and particle board. Salt (NaCl) is a dry chemical which is shipped worldwide in vast quantities.

3. What partnerships, if any, formed to help develop and potentially transfer the technology?

Los Alamos participated in a Cooperative Research and Development Agreement (CRADA) with Jenike & Johanson. Together, Jenike & Johanson and Los Alamos are leveraging their experience, expertise and prior successes to develop this integrated technology that will achieve significant gains in integrated bio-refinery operational reliability leading to global commercialization of biomass as an economically viable resource for fuels and chemicals. During their R&D collaboration, two objectives focused on increasing integrated bio-refinery operational reliability:

- Design, build, and demonstrate “smart” transfer chutes for handling corn stover biomass solids
- Design, build, and demonstrate on-line acoustic sensors for measuring moisture content of corn stover biomass solids

The primary goal of these objectives was integrating the “smart” transfer chutes with the acoustic sensor technology to provide novel bulk solids handling and transport that increase integrated bio-refinery operational reliability. The integrated use of these technologies is the ground-breaking innovation to improve the economic viability of integrated bio-refinery, expand the marketability

biofuels, and diversify liquid fuel resources. The partnership will enable Jenike & Johanson to advance their smart chutes to other applications beyond biomass.

4. What patents were filed or planned to be filed?

Los Alamos has more than 100 patents and decades of pioneering expertise in developing acoustic sensors serving a wide range of applications. For biofuels, the combined acoustic sensor and "smart" chute technology will leap frog the industry's standard stationary chute design by discarding undesired material before it plugs the chutes, damages equipment, and causes costly downtime. Los Alamos and Jenike & Johanson are continuing to collaborate through a CRADA with the goal of coupling the technology by the end of the year and potentially creating additional intellectual property.

The technology is specifically based on these patents listed below for acoustic monitoring:

- Acoustic imaging of objects in optically opaque fluids – *United States Patent* ***US10331025****,* Jun 25, 2019
- Apparatus and method for acoustic monitoring of steam quality and flow – *United States Patent* ***US10309932***, Jun 4, 2019
- Methods for measuring properties of multiphase oil-water-gas mixtures – *United States Patent* ***US10088590***, Oct 2, 2018
- Broadband unidirectional ultrasound propagation – *United States Patent* ***US9843400***, Dec 12, 2017

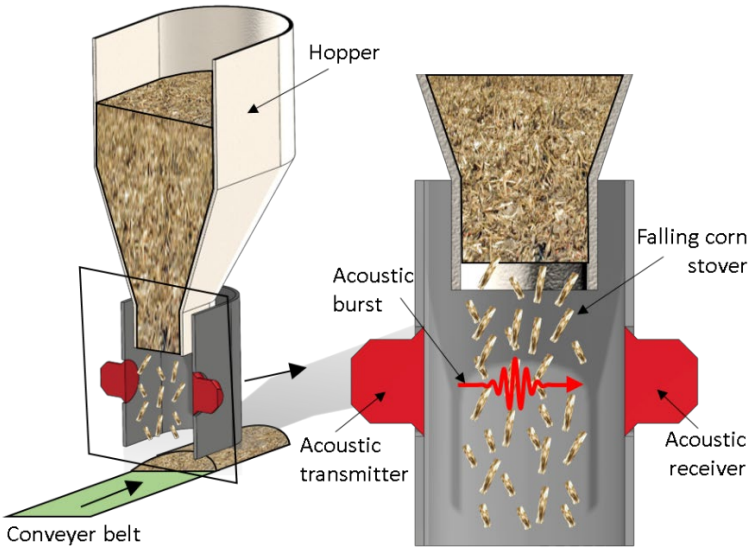

Figure 1 On-line acoustic sensors measure biomass moisture content to provide active feedback control.

Figure 2 A prototype conveyor at Los Alamos National Laboratory moving bulk material.